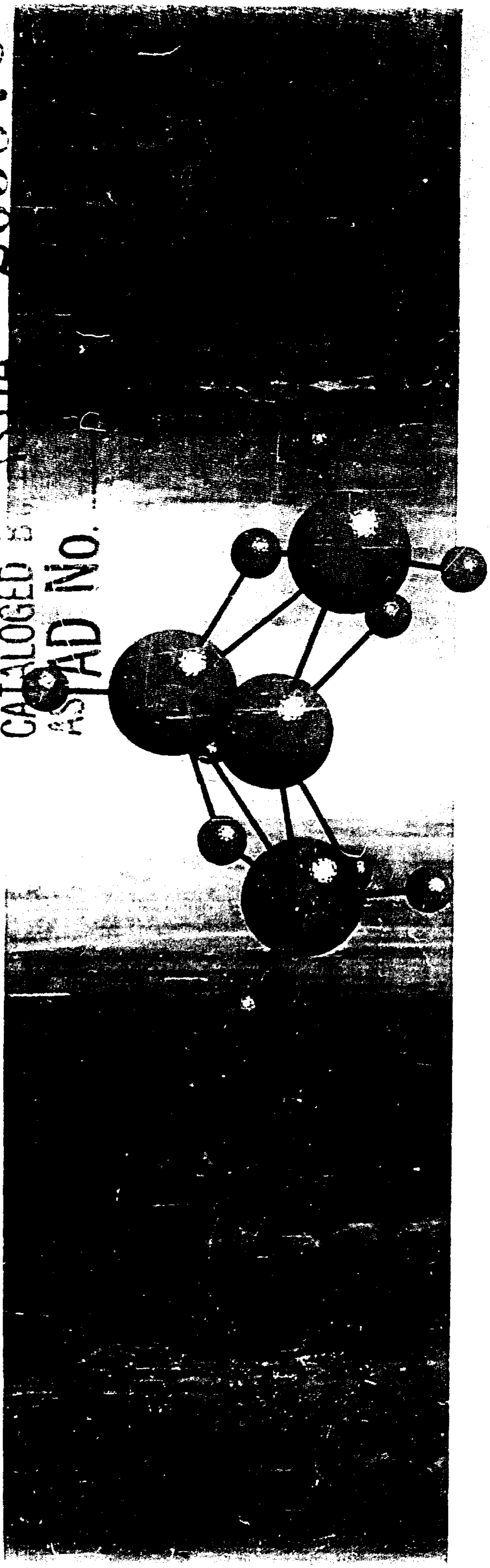

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Research Report

DESIGN OF SAFETY EQUIPMENT
FOR HANDLING HIGH-ENERGY
RESEARCH MATERIALS OF
UNKNOWN SENSITIVITY

August 4, 1961

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RESEARCH REPORT

Design of Safety Equipment for Handling High-Energy Research Materials of Unknown Sensitivity

August 4, 1961

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INTRODUCTION

A need often arises for protection of personnel while they handle high-energy research materials of unknown sensitivity. In many instances the safety precautions are inadequate because full protection implies to many individuals, costly equipment and delays in the operations.

Callery Chemical Company has designed and is using safety equipment which is inexpensive and which results in very little delay in operations. The equipment is built of commonly available materials (steel plate, aluminum pipe, etc.) and can be fabricated easily by the user. Tests have proven the effectiveness for personnel protection and use of the equipment has resulted in very little delays in operations.

This special report is distributed by Callery Chemical Company to those receiving LPIA publications. Questions should be directed to Dr. R. A. Brown, Callery Chemical Company, Research and Development Division, Callery, Pennsylvania.

The cooperation of 6593 Test Group (Development), Edwards, California is gratefully acknowledged.

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

(Continued)

SUMMARY

The design of systems for protection of personnel while preparing, transporting and testing high-energy research materials of unknown sensitivity is discussed in this report. Facilities for preparing and handling such materials have been built at the Callery Research and Development Laboratories. The equipment and constructions have been tested with explosions of tetryl, of approximately 50 percent greater weight than the maximum of the experimental material to be handled. In the construction, personnel safety was the prime consideration and equipment protection was of secondary concern.

DISCUSSION

Equipment that allows easy handling of high-energy, sensitive materials while providing for safety of operating personnel is discussed in detail below. This equipment is divided into three general groups:

(1) Construction that protects personnel if any or all of the contained material detonates.

(2) Equipment that enables simple, remote performance of operations.

(3) Equipment for easy and safe transportation of the sensitive material from one area to another.

Designs to be used in the first and third groups above were tested with exploding tetryl prior to their approval for use. The tetryl charge in each case was about 50 percent greater in weight than the maximum quantity of research material to be handled in the equipment under test.

(1) Construction

Protective enclosures are necessary for the handling areas to shield personnel from shrapnel and flame that might result from an accidental explosion. The walls of each enclosure are built of mild steel plate completely welded together for strength and weather protection. These walls also provide a means of mounting the remote handling equipment. Use of the steel walls for mounting is kept to a minimum to avoid weakening these walls. The outside of one such area showing mountings of valve handle extensions can be seen in Figure 1.

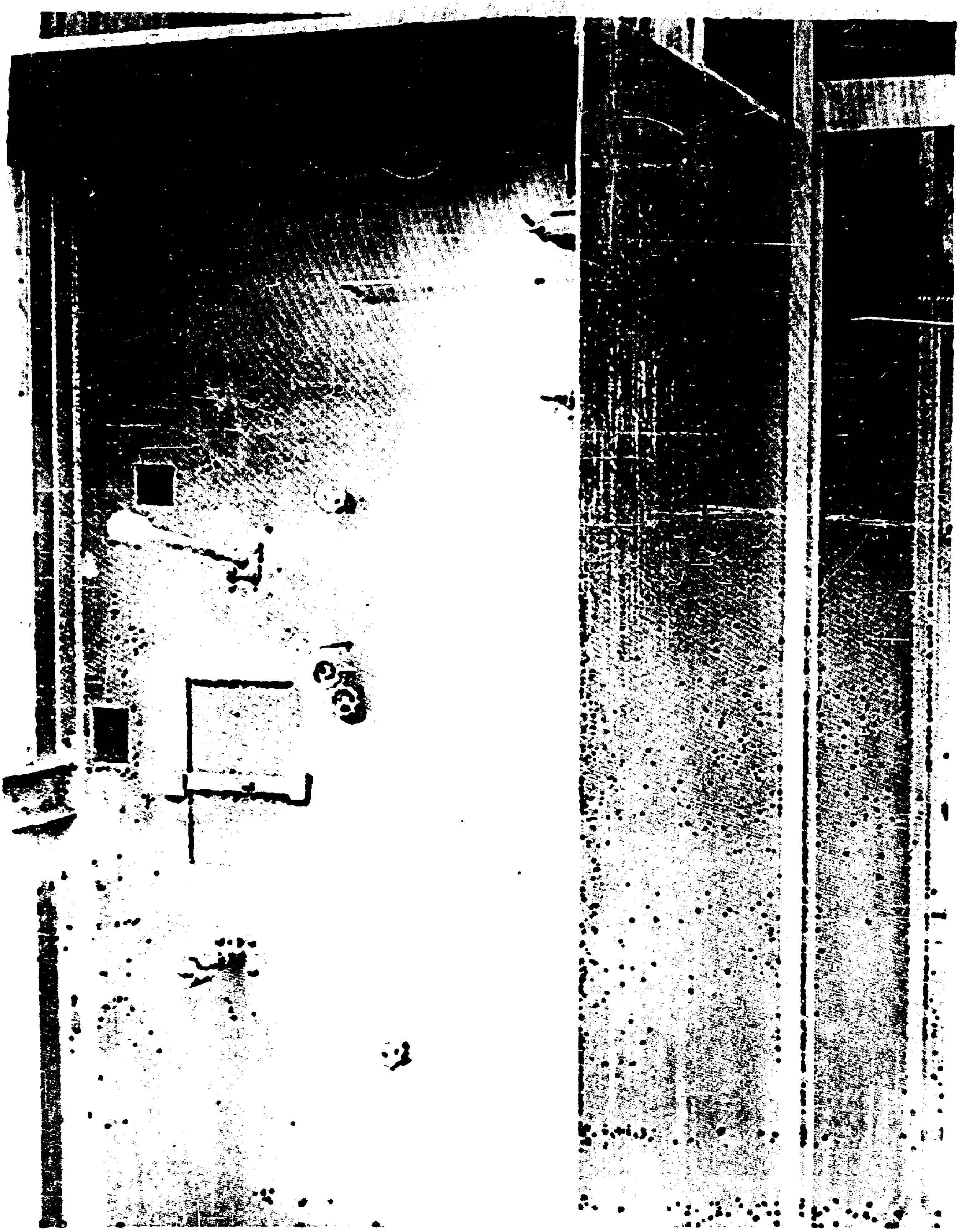


Figure 1
Protective Wall of Area Showing Valve Handle Extension Mountings

The enclosures described in this section have been adequate for protection of the operating personnel. They have been tested with explosions of tetryl, and they were subjected to an accidental explosion of research material. In all cases, damage to the enclosures was negligible and protection of the operating area was very good.

One wall is built of a relatively soft material, such as insulation, to fall away quickly under pressure. In this way, any pressure generated by an explosion is relieved before the steel walls are affected. These soft walls are also capable of stopping or slowing down shrapnel before falling away. The soft wall is always located on the opposite side of the system from the operating area for maximum personnel safety.

The design limits for each area are one-half pound total with no more than 100 grams in any container at one time. Containers are installed no less than one foot apart and no less than two inches from the protective steel walls. Where possible, containers are made of glass to avoid high confinement of exploding material and to reduce the amount of steel shrapnel produced by an internal explosion.

To further lessen the possibility of shrapnel penetrating the steel walls, a minimum of two steel plates is used, each at least one-fourth inch thick and separated by at least one foot. Within the limits of research material mentioned above, it seems reasonable to assume that the steel plate nearest the explosion

will slow down (if not stop) any metal fragments so that penetration of the second plate will be negligible. Another advantage of the plate separation is that the plates provided two points of support for the remote handling equipment (for example, valve handle extensions). Both inside and outside steel walls with the mountings of valves and their extension handles can be seen in Figure 2.

One inch thick Plexiglas windows are installed in both steel walls so that containers and operations can be observed behind the inside steel wall. The Plexiglas areas are kept to a minimum to avoid weakening the steel plates. Frames are built of steel angle for the windows so that the windows are completely enclosed and overlap the hole in the steel plate by at least one inch on every side. A typical window installation is shown in Figure 3.

Steel doors were installed in the steel walls for personnel access to the equipment. The doors were provided with bar latches to prevent their flying open from the force of an explosion in the equipment area. A typical safety door installation is shown at the left side of Figure 4.

One step in the handling and operating procedure does not take full advantage of the above construction protection. This step is the introduction of the research material into one of the systems. For this step additional personnel protection is necessary. Since the operation requires moving a container of research material through both the outside and inside steel plates, small holes are necessary in both plates. Adequate steel doors can be installed to retain two-

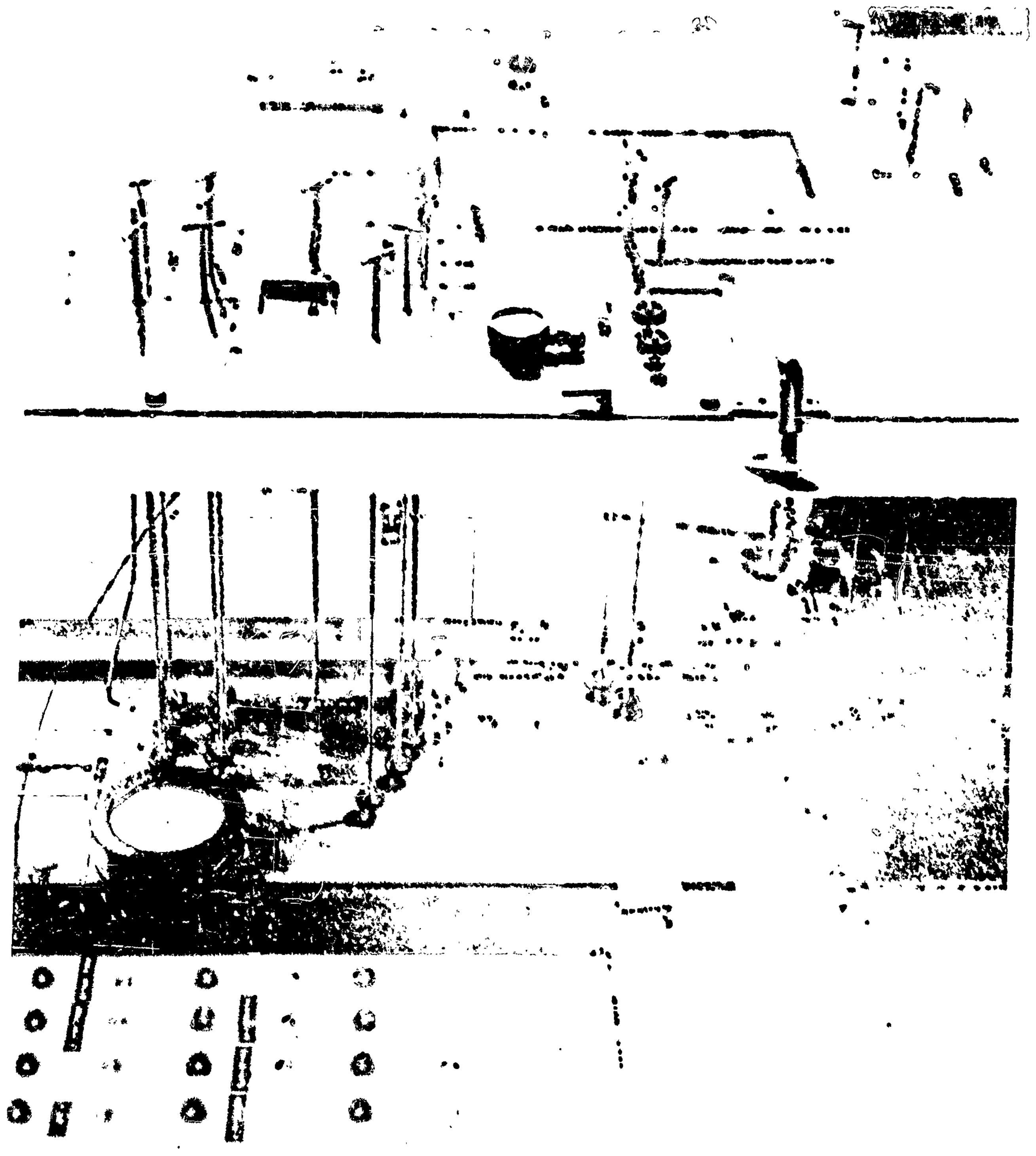


Figure 2
Valve Mountings on Inside Steel Wall With Extension Handles Through Outside Steel Wall

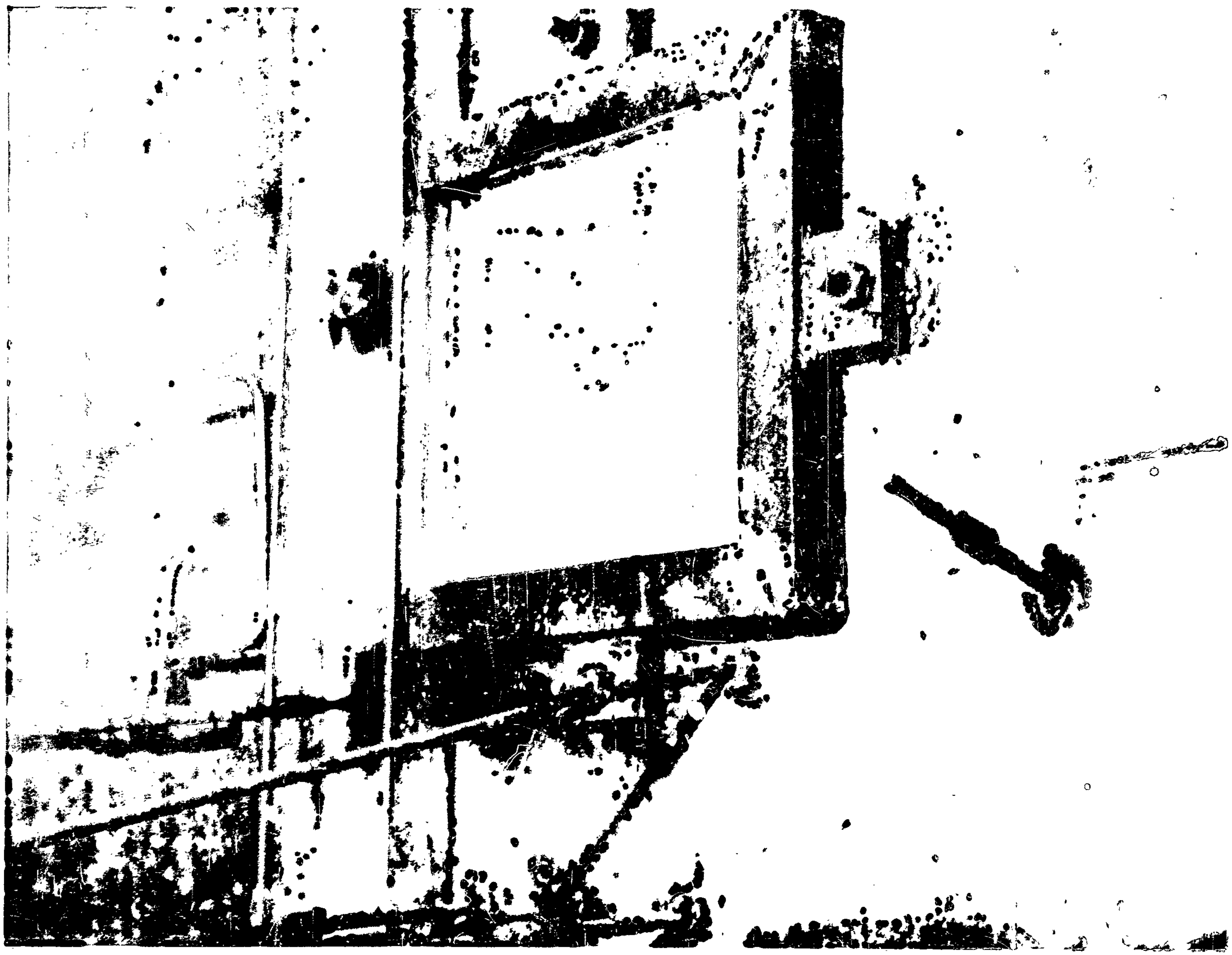


Figure 3
Window Installation--Inside of Outer Steel Wall

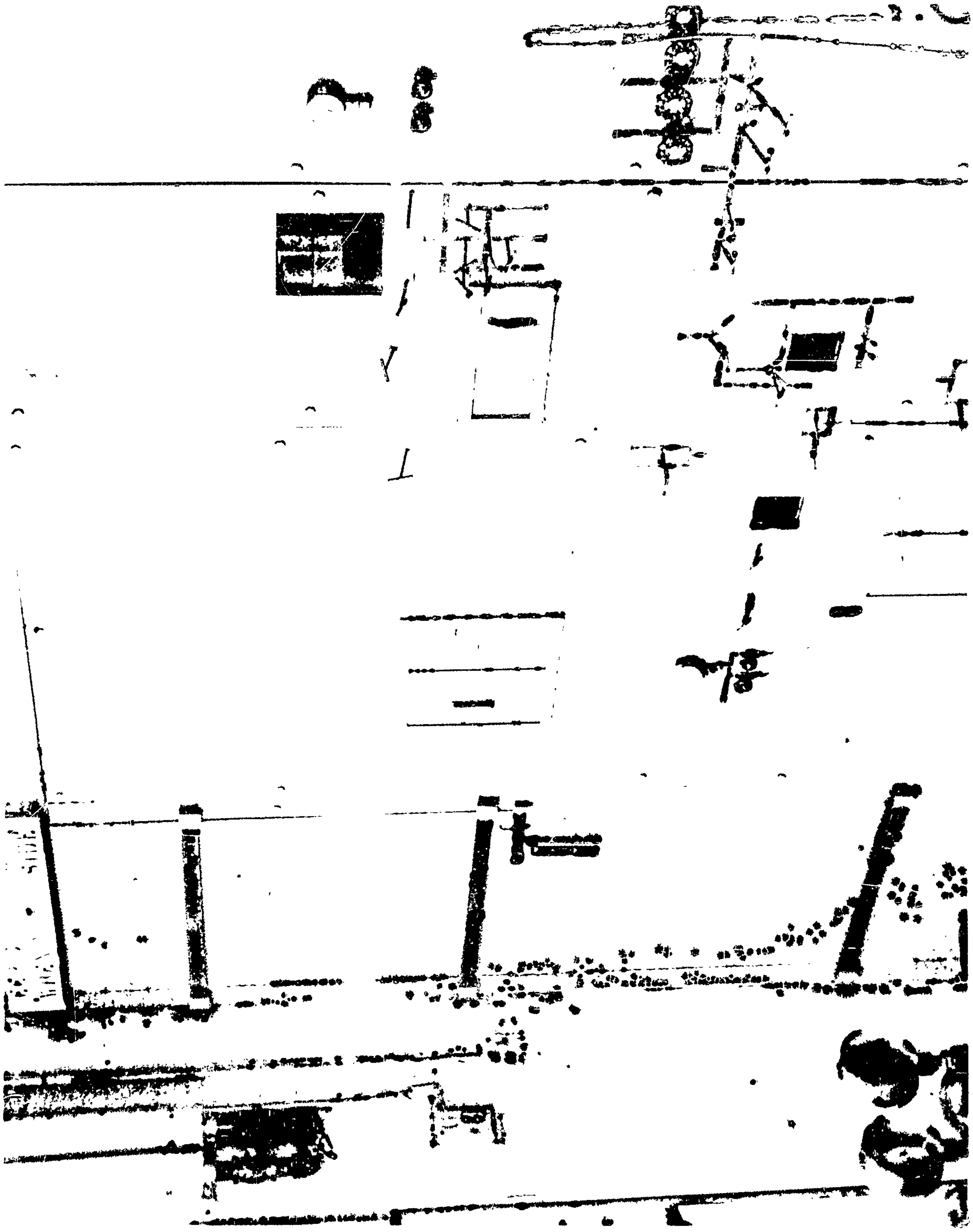


Figure 4
Outside Steel Wall of Operating Area With Safety Door At Left

wall protection when the doors are closed. However, when either door is open a single plate separates the operator from the process system. An introduction hole with latched door is shown in Figure 5. This door is hinged and opens inwardly. Figure 6 shows a sample of research material being moved into the unit through the introduction hole. The research material is inside the safety carrier (discussed in detail in Section 3 of this report) at the end of the carrying rod.

A steel tunnel is welded to the inside of the outer steel plate to improve personnel protection. An illustration of a tunnel installation is shown in Figure 7. The tunnel serves to reduce the area from which fragments may come to the open door. The tunnels are made of steel plate at least one-quarter inch thick with both sides and the bottom welded along all seams to each other and to the wall around the doorway. The tops of the tunnels are made of the same plate as above but are laid, without welding, across the tops of the side pieces. When an explosion occurs inside the tunnel the top will be blown away and the tunnel will not direct the force of the explosion, as well as glass fragments, out the tunnel toward the operating personnel.

During the introduction operation the container of research material must be passed through the outside wall, moved to the hole in the inside wall, and then passed through the inner wall to the process system. These two holes may not face each other because of the open path from the process system to the operating area available to any flying particles. However, the personnel protection is only

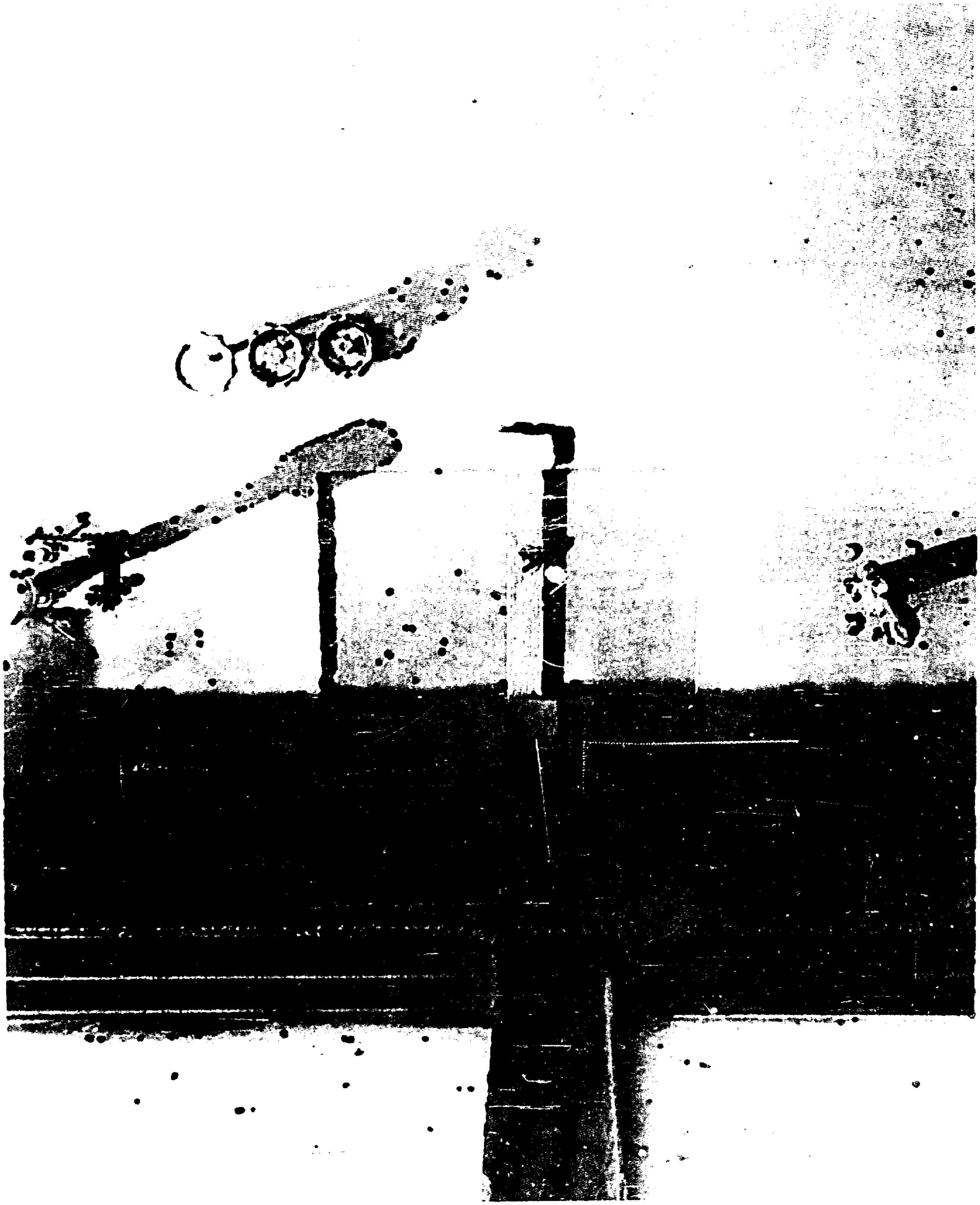


Figure 5
Introduction Hole With Latched Door

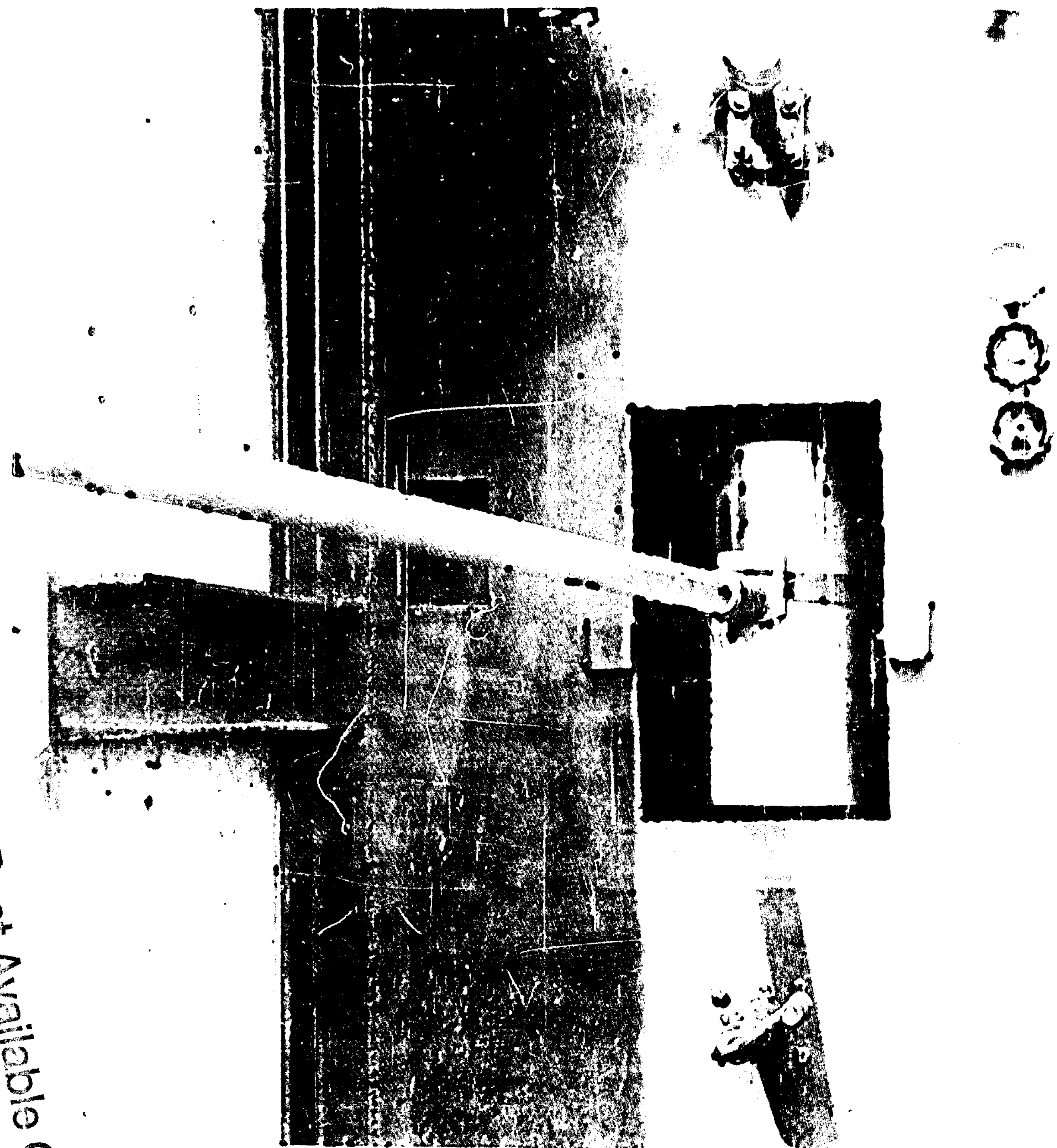


Figure 6
Introduction of Research Material Inside Safety Carrier

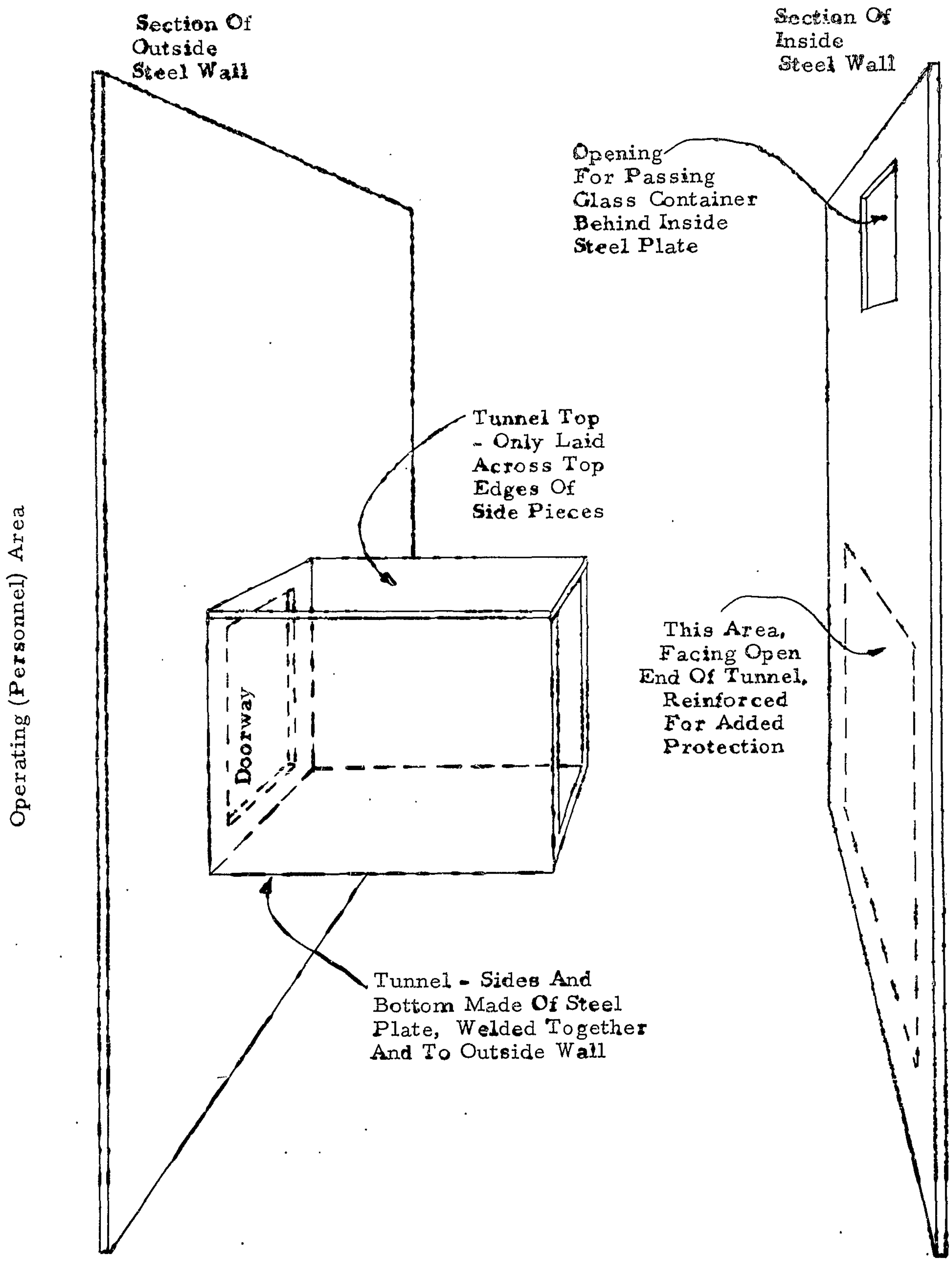


FIGURE 7

ILLUSTRATION OF TUNNEL INSTALLATION

one wall when the container is between the two walls, being moved from one entrance hole to the other.

The limit of material chosen for each introduction is thirty-five grams. Single wall protection appears adequate for this quantity if the container is made of glass. If larger quantities of material are required in the process system, more than one transfer will be necessary.

Sliding or hinged doors are acceptable for both the outer and inner wall introduction holes. Hinged doors are placed on the inside of the wall while the sliding types are installed on either side of the wall. In all of the installations the doors overlap their openings by at least one inch on each side. The sliding doors are fully enclosed on three sides by steel angle, completely welded. Small sliding doors can be seen on the outside steel wall shown in Figure 4.

Two tests were made with exploding tetryl pellets to substantiate the safety of the construction as described above. In the area chosen for the tests, all protective plates, windows and doors had been installed but no process equipment had been placed because of the expense of repairing and replacing this equipment. It was felt that the process equipment did not add enough severity to the test to justify the expense.

For both tests, the situations chosen simulated those that would be most dangerous during actual operation. The weight of tetryl charges used, equaled or exceeded the maximum weight of research material anticipated in each situation.

Test No. 1 was made to simulate an explosion of material in a glass storage container near the inside steel wall of one of the handling areas. A diagram of the arrangement of the tetryl pellets is shown in Figure 8. The pellets were 50 grams each, 1.5 inches in diameter and 0.5 inches thick. The pellets were initiated simultaneously, each by a U. S. Army Type J2 blasting cap. A six frame sequence of this test, taken by a motion picture camera at 50 frames per second, is shown in Figure 9.

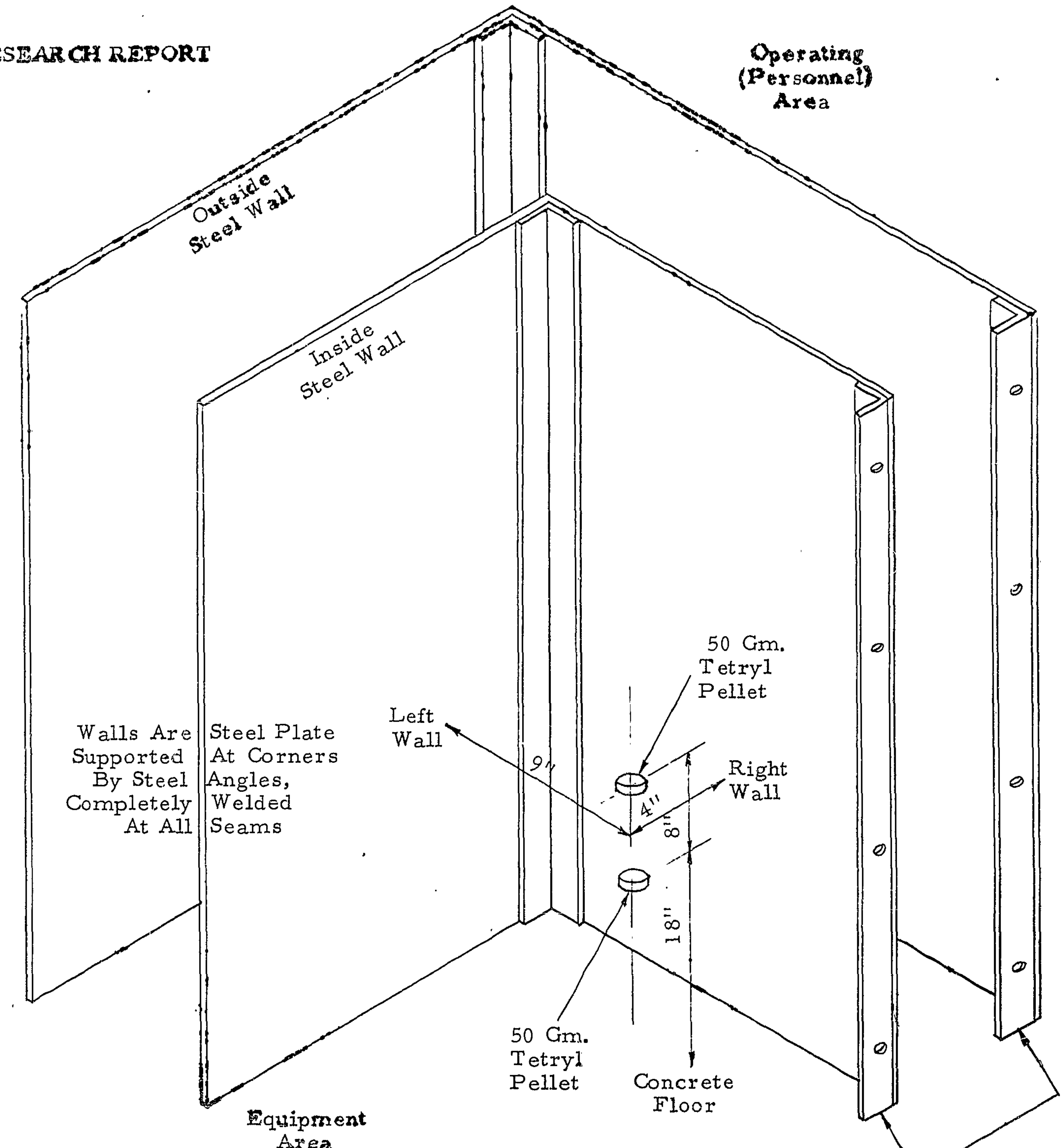
No visible damage was done to the structural steel or to the windows. About half of the anchor bolts that held the inside steel wall to the concrete wall and floor were loosened, and two bolts were bent. The loosened and bent bolts had to be replaced.

Test No. 2 was made to simulate an explosion of material in the transport carrier while the carrier was inside the steel tunnel. A single 50 gram tetryl pellet was used. The pellet and its initiation were the same as in the first test. The transport carrier is shown in Figure 10, and described in Section 3 of this report. The tunnel was constructed of one-fourth inch thick steel plate and was 17 inches high, 12 inches wide and 15 inches long. A six frame sequence of this test is shown in Figure 11.

The effects of the blast on the structure were the same as in the first test. The bottom and top plates of the tunnel were badly bent but were still whole. The weld joining the bottom piece to one of the side pieces was broken.

FIGURE 8

ARRANGEMENT OF TETRYL PELLETS FOR TEST NO. 1

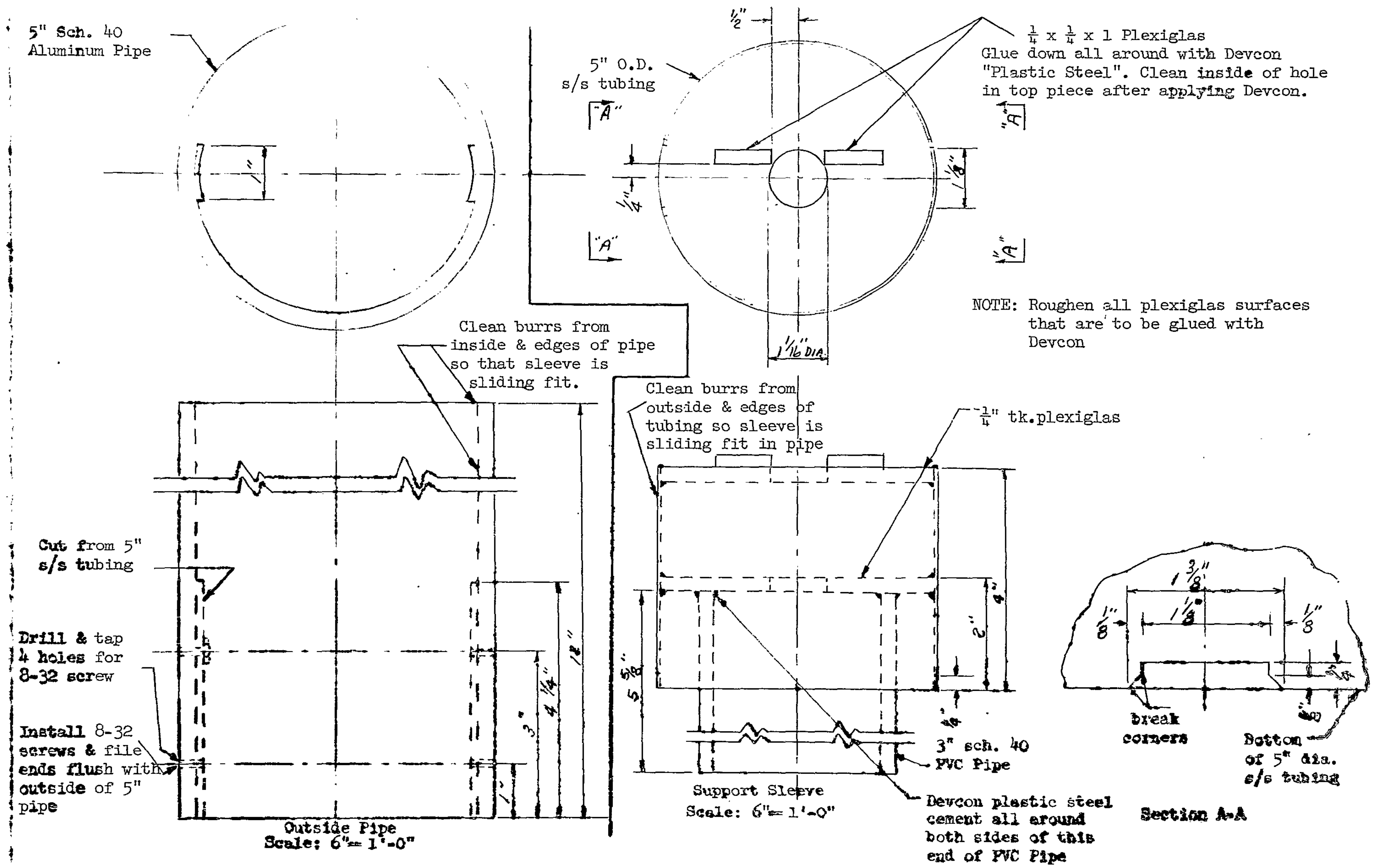


These steel angles held to concrete wall with 3/8" anchor bolts through holes shown.

Note: Angles were used similarly to fasten the plates to the concrete floor.

Figure 9
Test No. 1 (50 Frames Per Second)
Enclosure Test

ꟼORT FIGURE 10 METAL SAFETY CARRIER



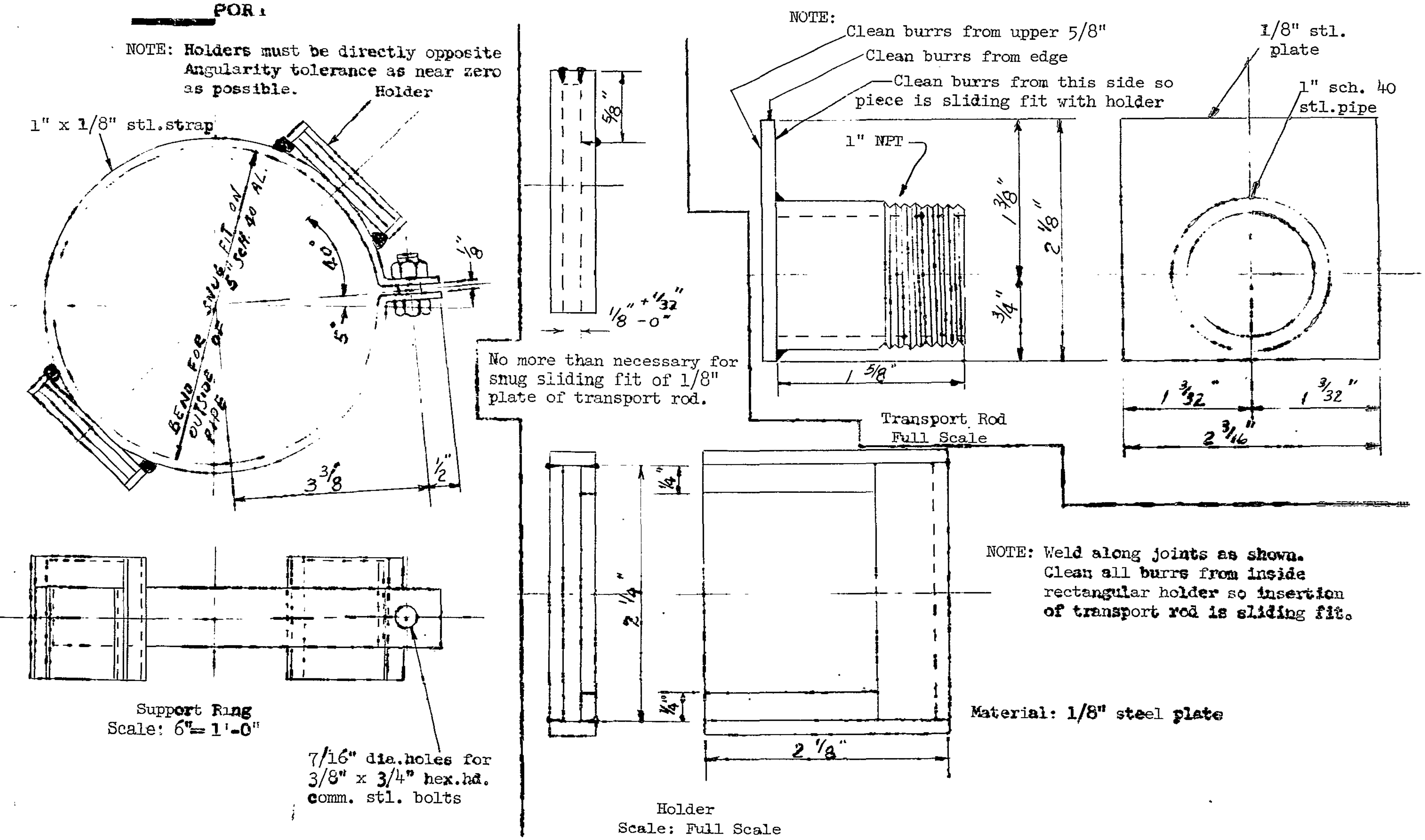


FIGURE 10 METAL SAFETY CARRIER (Continued)

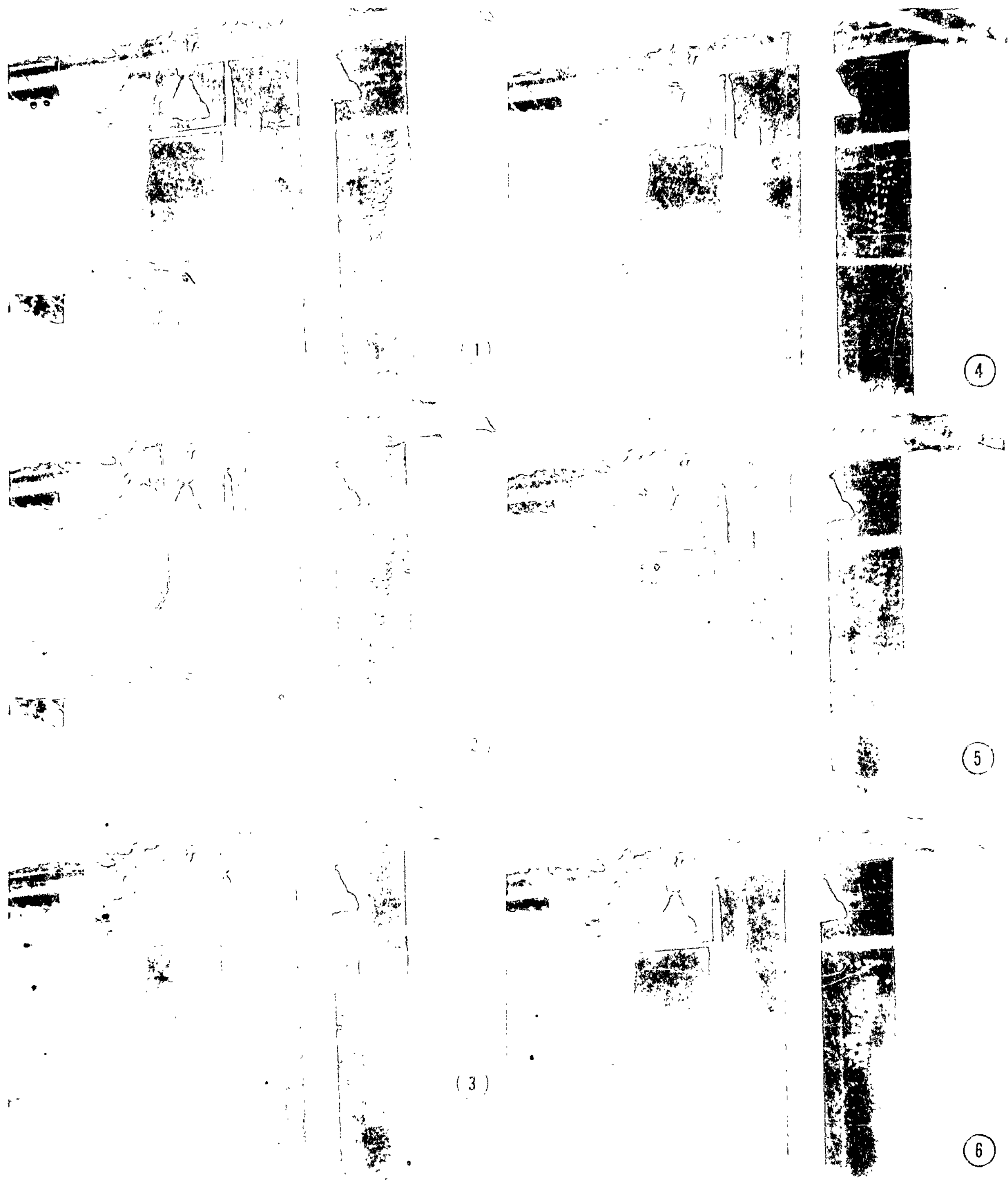


Figure 11
Test No. 2 (50 Frames Per Second)
Tunnel Test

The loose top plate was thrown through a five-eighths inch thick plywood sheet used as a roof and was found lying on the roof. The tunnel top had probably been deflected by the steel blast mat located about three feet above the plywood roof. The effects on the transport carrier were the same as those noted in Table A of Section 3, Test No. 7.

The results of these tests indicate that the construction is adequate from the standpoint of safety to the personnel in the operating area. Damage to the structural steel was minor and very few repairs were necessary. However, extensive damage would probably have resulted to the process and handling equipment.

Further evidence to support the above conclusions was the effects of an explosion that occurred in one of the systems during actual operation. At least 40 grams of research material exploded in this area, destroying essentially all of the glass components and sections of the stainless steel piping as well as several pieces of metallic equipment. The soft wall fell away and several pieces of broken pipe fittings were found imbedded in this wall. The one inch thick Plexiglas at the inner walls was gouged in many places and some minor damage was evident to the steel structure of the inner walls.

Two persons were in the operating area when the explosion occurred and they were completely unharmed. On the basis of the tetryl tests and the accidental explosion, the structures appear adequate for full protection of the operating personnel.

TABLE A

Safety Tests

Test No.	Explosive Charge *	Location	Test Results
Area Construction			
1	Two 50 gm. Tetryl pellets, separated 8" (from centers).	Inside inner steel envelope (built of 3/8" boiler plate) near corner. 4" from one wall, 9" from other, bottom pellet 18" above floor. See Figure 8.	No visible damage to structural steel except slight damage to anchor bolts (holding steel plates to concrete wall). See Figure 9.
2	One 50 gm. Tetryl pellet.	Charge inside transport carrier (as in tests 7 & 8) inside steel tunnel (1/4" boiler plate), 17" high, 12" wide, 15" long. Top plate of tunnel only lying in place other joints welded. See Figures 7 and 10.	Bottom and top plates of tunnel badly bent, weld on bottom plate torn. Top plate thrown through 5/8" thick plywood roof, found resting on top. Effects on structure same as in Test No. 1 See Figure 11.

* Initiated by U.S. Army Type J2 blasting cap

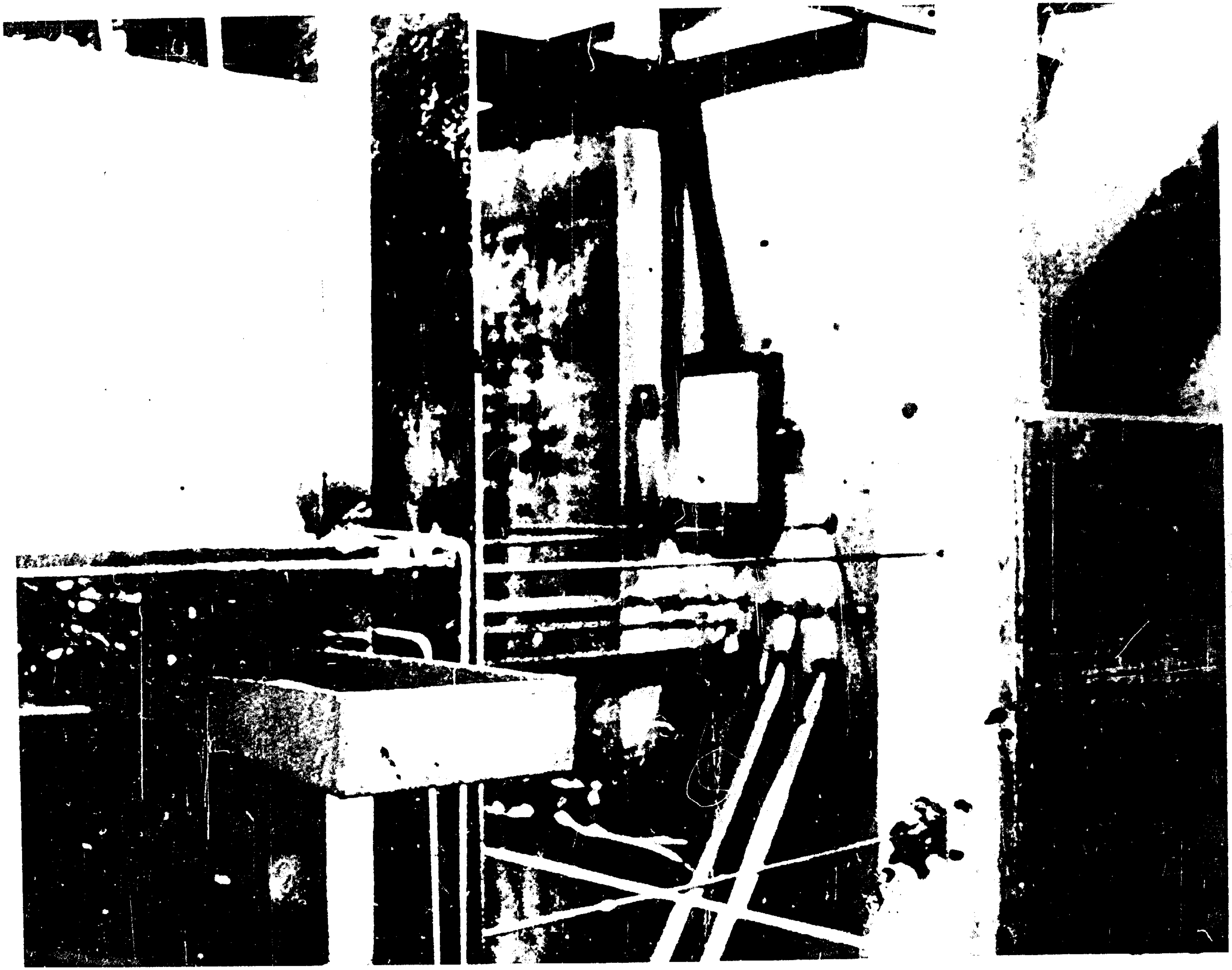


Figure 12
Extension Handle Installation

TABLE A

(continued)

Test No.	Explosive Charge *	Location	Test Results
Transport Carrier			
3	5" sch. 40, mild steel pipe, 12" long	50 gm. tetryl pellet, 1-1/2" dia. 1/2" thick.	Circumferencial bulge (1/8"), Approximately 2" wide at middle of pipe. See Figure 19.
4	Same as Test No. 3	Two tetryl pellets (as in Test No. 3), stacked.	Same as Test No. 3 but bulge was 1/2" and approximately 4" wide. See Figure 20.
5	5" sch. 40 aluminum pipe, 12" long	Same as Test No. 3	Bulged to maximum of 1-5/8", approximately 6" wide. Five severe longitudinal splits. See Figure 21.
6	5" stainless steel tubing, 1/8" thick wall, 12" long	Same as Test No. 3	Same as Test No. 4. See Figure 22.
7	Same as Test No. 5 but with 4" length of tubing (same as in Test No. 6) in center.	Same as Test No. 3	Bulged both pipe and sleeve as in Test No. 3 but to maximum of 3/16".
8	Same as Test No. 7	Same as Test No. 3, See Figure 18.	Same as Test No. 7. See Figures 16 and 17.

* Initiated by U.S. Army Type J2 blasting cap

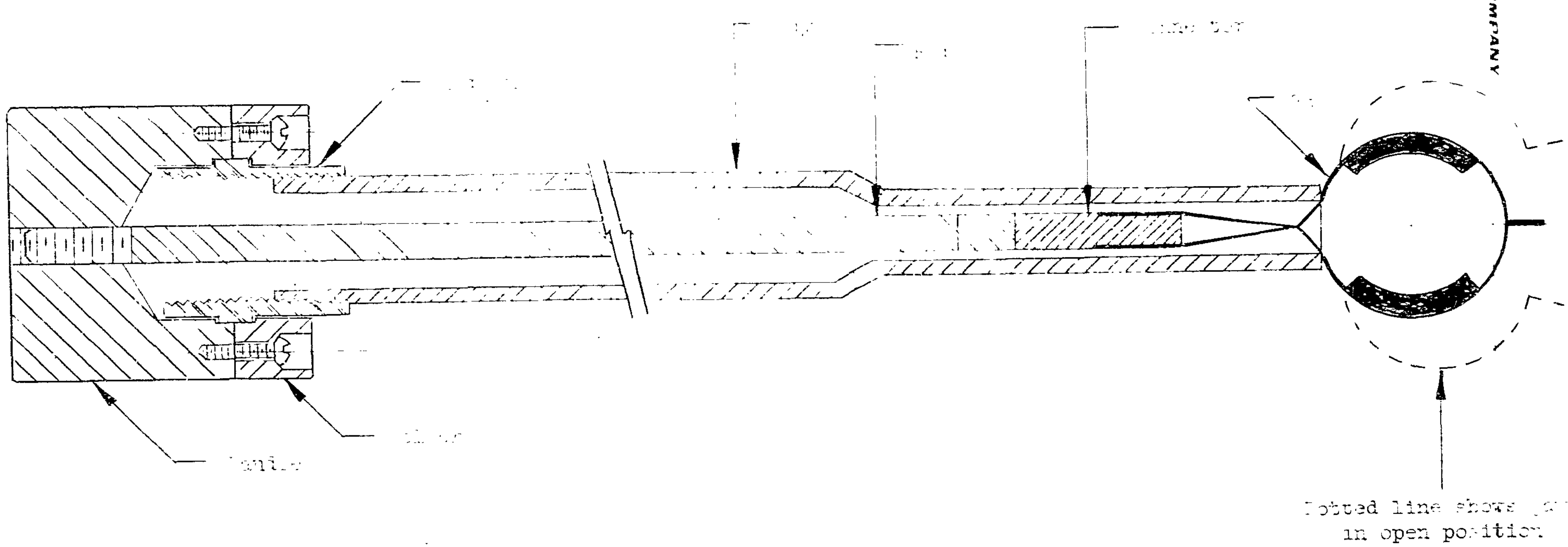


FIGURE 15

REMOTE MANIPULATOR

Scale: Full Size

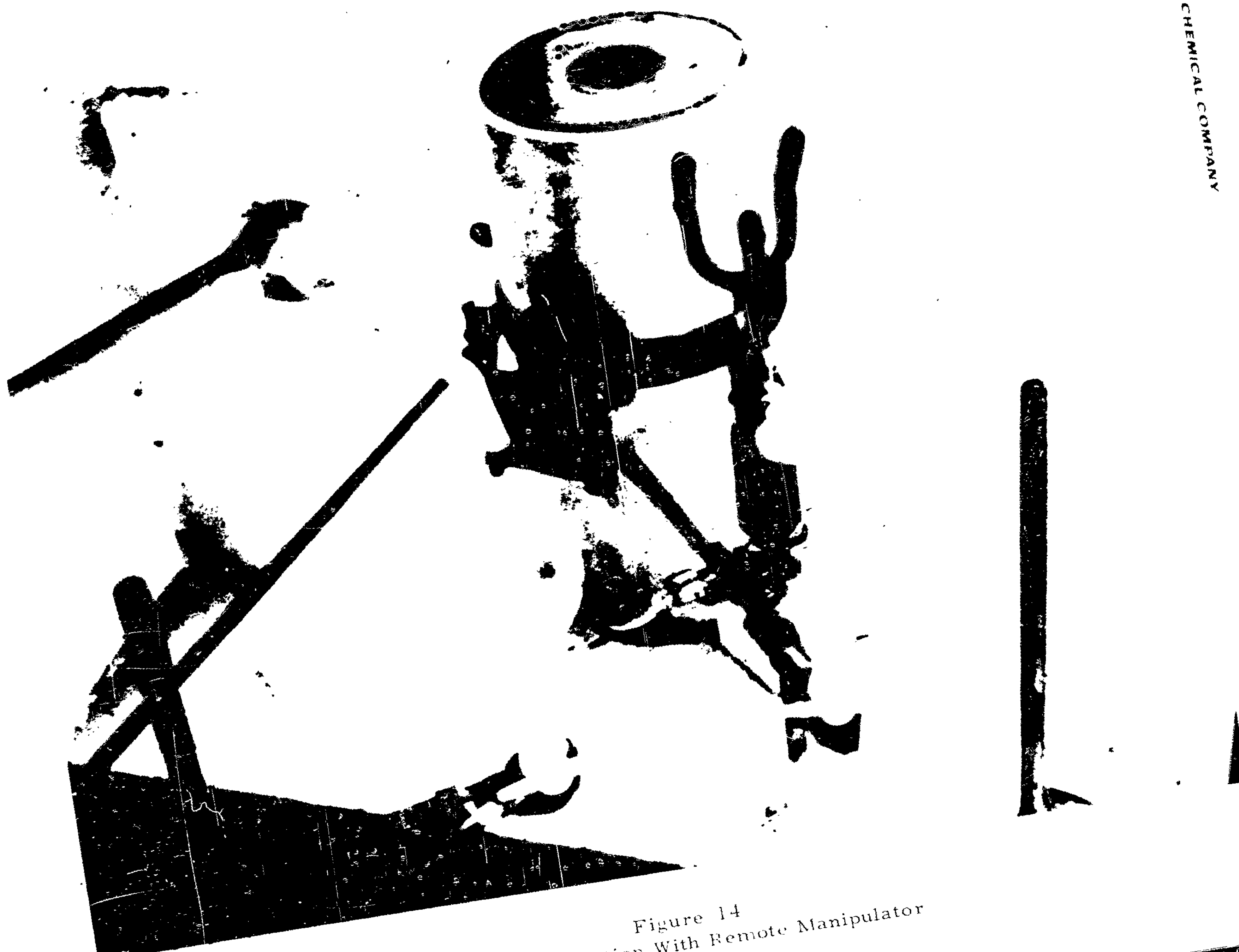


Figure 14
Typical Operation With Remote Manipulator

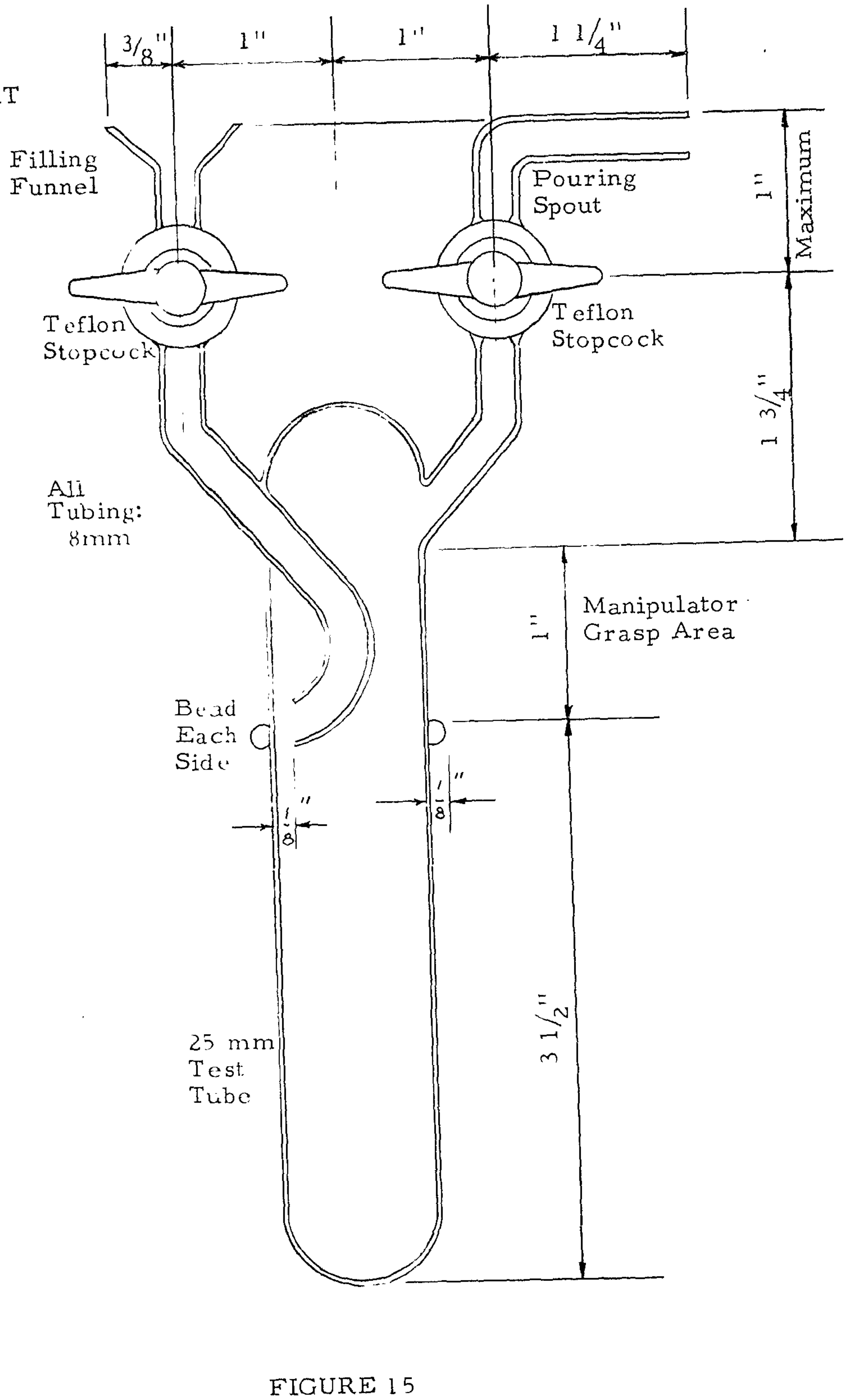


FIGURE 15

GLASS CONTAINER

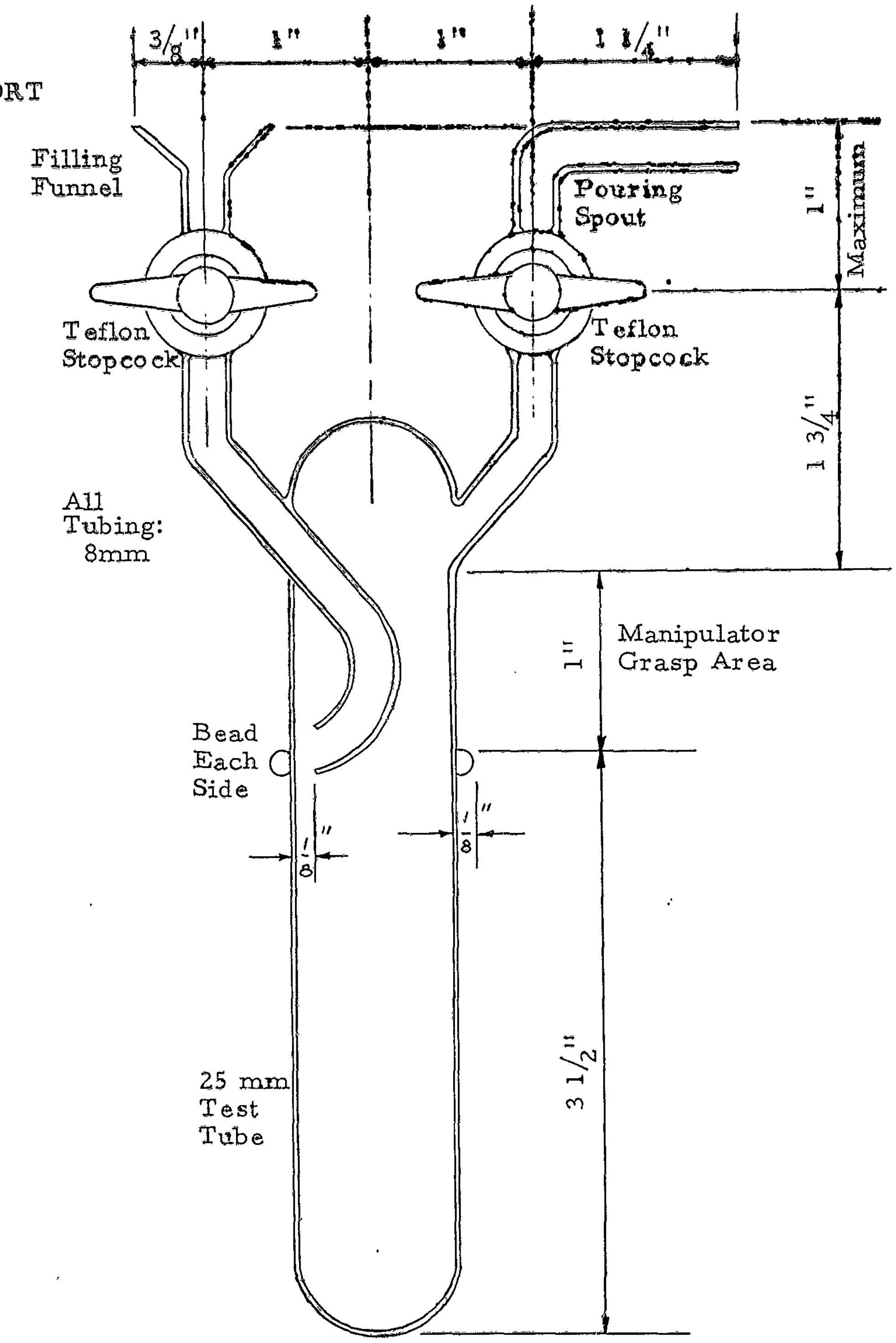


FIGURE 15

GLASS CONTAINER

A magazine for the storage of the research material in quantities up to two pounds has been built near one of the systems. The metal storage container is located in a hole in the ground with six inch thick concrete walls. This type of construction was used so that an explosion will be directed upward, and not toward inhabited buildings around the area, 100 to 200 feet away. The hole is covered by a single piece of five-eighths inch thick plywood and is surrounded by a three foot high sandbag wall. A sandbag wall also protects the transfer piping through which research material is moved from the operating system to the storage magazine.

(2) Remote Handling Equipment

The remote handling equipment consists mainly of:

(a) jack extension handles,

(b) extension handles for valves and stopcocks, and

(c) manipulators for remote handling of small containers of research material.

Since the process equipment and piping are located behind the inside steel wall, the extension handles are of suitable length to operate valves, stopcocks, or jacks mounted on or behind the inside wall. Figure 12 illustrates such valve and stopcock handle extensions. The rods in the lower center are the extensions. A Plexiglas window for viewing valve and stopcock operation is shown in the center of Figure 12.

The manipulator design is shown in Figure 13. The jaws can be remotely closed around a small container so that research material can be moved from place to place, poured or mixed with other materials. Figure 14 shows a typical manipulator operation. The glass container (Figure 15) has been grasped with the manipulator for pouring. The aluminum safety carrier can be seen in the center of Figure 14. The sleeve has been remotely raised (the top Plexiglas support plate is flush with the top of the carrier) to expose the glass container so that it can be grasped with the manipulator.

(3) Transport Equipment

A transport carrier was designed so that quantities up to thirty-five grams of research material can be safely transferred from one system to another. A portable carrier is required in which research material can be moved with complete safety to the operating personnel.

The carrier design which meets all necessary requirements is shown in Figure 10. Carriers made according to this drawing passed all explosion tests and are light enough to be portable. In addition, the mechanical design allows easy insertion and removal of the glass container with the research material. Please note that "container" refers to the glass container (illustrated in Figure 15) in which the research material is handled and that "carrier" refers to the metal pipe and its auxiliary parts (Figure 10) inside of which the glass container

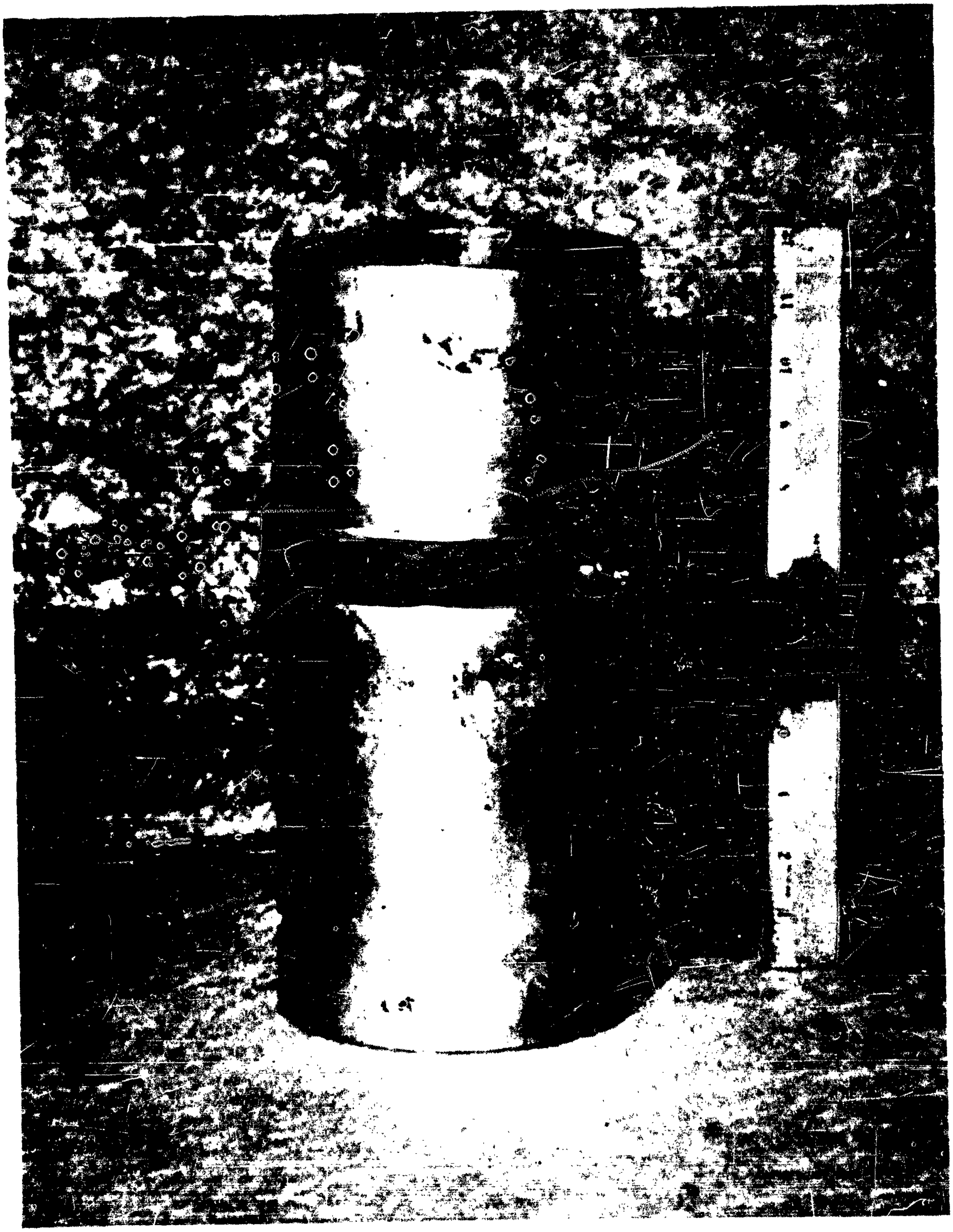


Figure 16
Test No. 8--Effect on Carrier Pipe

Figure 17

Test No. 8--Final Carrier Design

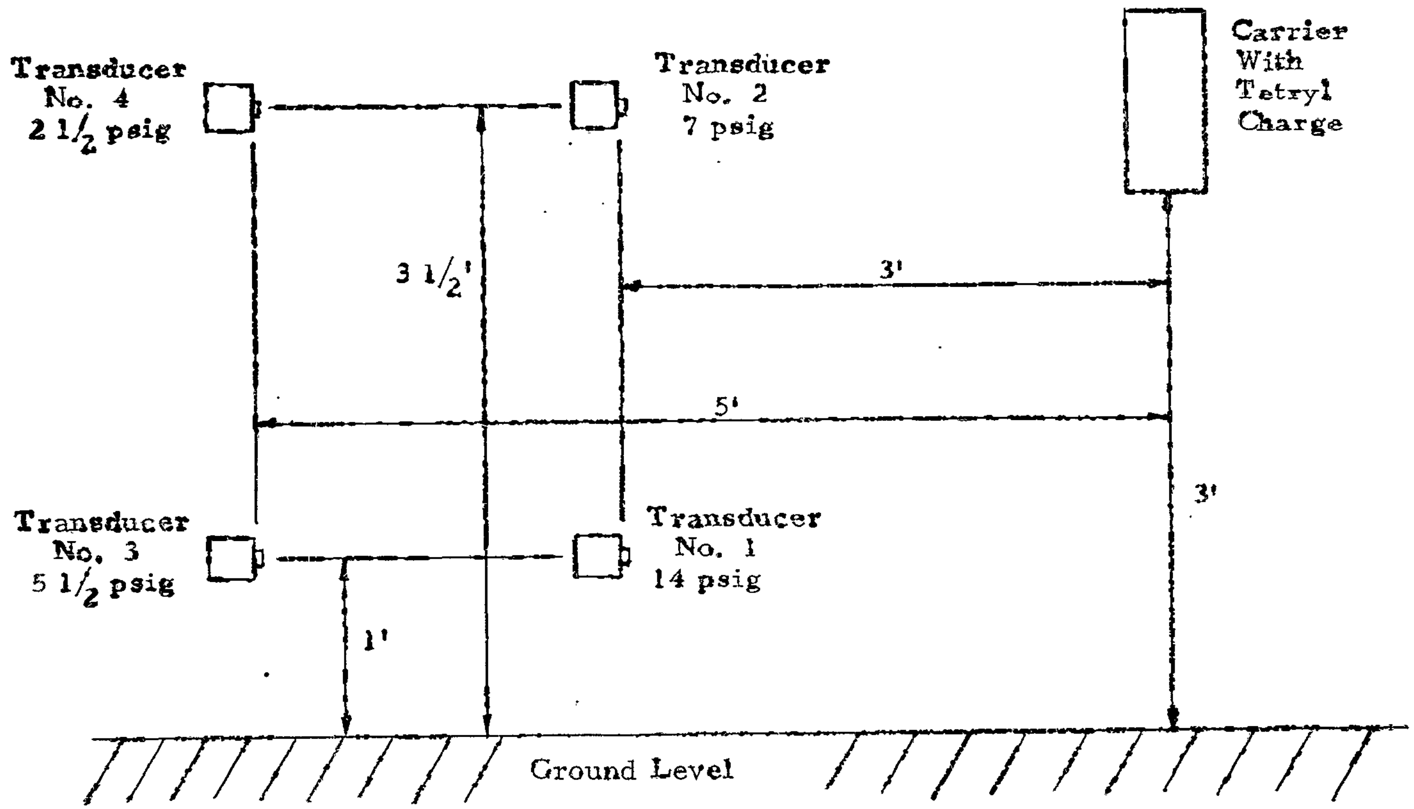


FIGURE 18

TRANSDUCER LOCATIONS AND MAXIMUM PRESSURES RECORDED

- TEST NO. 8

is placed for transportation. The carrier is the safety shield for personnel if a container of research material accidentally explodes during transport.

Protection against two hazards, shrapnel and the shock or pressure wave, is necessary if an accidental explosion occurs during transportation. Glass was chosen for the container material to avoid the problem of metal fragments. Experience had shown that upon detonation of the research material, the container glass was reduced to very fine particles. Larger parts such as Teflon stopcocks, however, were not powdered and it appeared that a safe carrier would have to contain such parts or direct their flight in a safe path.

For simplicity, the glass container, as shown in Figure 15, is built from a 25 mm test tube. Stopcocks are added to the filling and pouring lines to eliminate evaporation and spillage during transport. Thirty-five grams of research material, the transport limit, results in a liquid height of about one and three-fourths inches in the glass container. The plexiglas supports in the sliding sleeve are placed so that the liquid in the glass container will be in the center of the metal carrier for maximum safety.

The carrier material is aluminum, demonstrated in tests, not to rupture or fragment. A carrier built to contain all particles produced in an explosion of 35 grams would be quite heavy and could not be considered easily portable. A cylindrical carrier was designed to be used with open ends vertical. Particles from inside will then be directed straight upward or downward but not radially toward personnel in the vicinity.

Three carriers, built as shown in Figure 10, were tested with exploding tetryl. These tests were Nos. 2, 7 and 8 described in Table A. Only the Plexiglas supports were omitted for simplicity. In each of these three tests, a 50 gram tetryl pellet was placed along the axis of the carrier, halfway between the ends. The stainless steel tubing sleeve was also centered in the aluminum pipe. The tetryl detonations were initiated by U. S. Army Type J2 blasting caps.

The effects on the carrier were the same in all three tests. The pipes were bulged as shown in Figure 16. The sleeves were expanded tightly against the insides of the pipes and had corresponding bulges.

Motion pictures were taken of Test No. 8 at fifty frames per second. A six frame sequence of the test is shown in Figure 17. These pictures indicated that the flame area on explosion extends to a maximum of two-and-one-half feet from the axis of the carrier at ground level. This result is the same as determined by the witness plates used in Tests No. 3, 4 and 5.

Atmospheric pressures were recorded near the test carrier during Test No. 8. The pressures were sensed by pressure transducers with their diaphragms completely exposed and facing the axis of the metal carrier. A diagram of the transducer locations and the maximum pressures recorded is shown in Figure 18.

To provide a reflective surface at ground level for the pressure wave issuing from the exploding tetryl, a large sheet of plywood was placed beneath the carrier and the transducer array. The plywood was treated with a high-gloss water sealer to make the top of the plywood more reflective to sonic disturbances.

Figure 19
Effect on Pipe--Test No. 3

Figure 20
Effect on Pipe--Test No. 4

The charge was exploded and the following pressures measured with the transducers:

Pressure Transducer No.	Distance from Carrier Axis	Distance above Ground Level	Maximum Pressure
1	3 feet	1 foot	14 PSIG
2	3 feet	3-1/2 feet	7 PSIG
3	5 feet	1 foot	5-1/2 PSIG
4	5 feet	3-1/2 feet	2-1/2 PSIG

In all cases, maximum pressures were attained and the readings had returned to essentially atmospheric pressure in one to two milliseconds from the time of first pressure rise.

The transducers located five feet from the carrier sensed the first pressure rise slightly more than two milliseconds after the first pressure rises were sensed at the transducers three feet from the carrier.

It has been concluded that the pressure peaks existing for such short duration will cause no physical harm to personnel standing three to five feet from the carrier when an accidental explosion (resulting from a quantity of material equivalent to 50 grams of tetryl) occurs within the carrier.

Figure 21
Effect on Pipe--Test No. 5

The complete carrier design as shown in Figure 10 is considered adequate for personnel safety when a glass container with up to 35 grams of research material explodes accidentally during transport.

Tests were made of other candidate carrier designs and they are listed in Table A. All tests were made with tetryl pellets supported in the center of the metal carriers. U. S. Army Type J2 blasting caps were used to initiate the tetryl detonations in all these tests.

In Test No. 3, mild steel pipe (5 inch diameter, schedule 40, 12 inches long) was used for the carrier. A single 50 gram tetryl pellet was used and the explosion bulged the pipe slightly at the center with no ruptures or cracks in the pipe. The effect on the pipe is shown in Figure 19.

Test No. 4 was similar to No. 3 except that the charge was two 50 gram tetryl pellets. The results were similar to those of Test No. 3 except the bulge was larger. Again no pipe ruptures or cracks appeared. Figure 20 shows the resultant pipe. This test was made to learn if the result of Test No. 3 was borderline. That is, a slightly larger charge than that used in Test No. 3 may have resulted in severe pipe damage and the safety of the pipe would have been marginal. The result of Test No. 4 indicated that the strength was adequate for 50 grams of tetryl and that the bulging that occurred in Test No. 3 was well within the limits of safety.

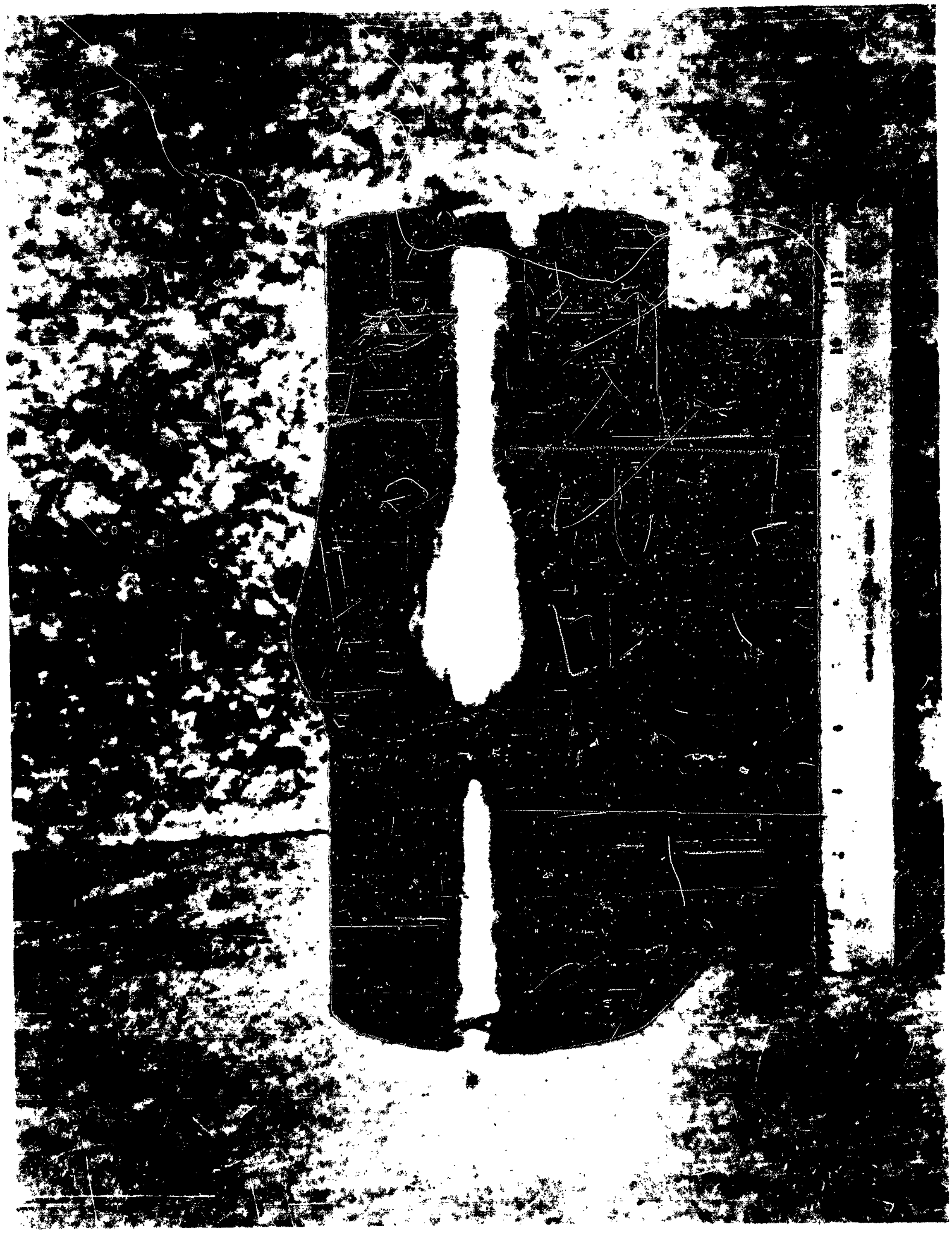


Figure 22
Effect on Tubing--Test No. 6

In Tests No. 3, 4 and 5 plywood and plastic sheet witness plates were u to determine the area of particle impact upon explosion. The witness plates w placed three feet below the bottom of the carriers, normal to the axis of the carriers. This was the approximate height above ground that the carrier woul held when carried by operating personnel at the end of a rod. Maximum radiu the downward spray was 2 to 2-1/2 feet in these tests. Four feet was chosen a the closest approach of personnel to the carrier (with container of material) at normal carrying height.

Although the mild steel carrier was of sufficient strength, it was too h to be carried for any distance at the end of a rod at least four feet long. If mechanical means were devised for handling the mild steel carrier, the simpl of the design would have been sacrificed.

Aluminum pipe (5 inch diameter, schedule 40, 12 inches long) was use in Test No. 5. A single 50 gram tetryl pellet simulated the research material The aluminum pipe bulged more than the steel pipe in either Test No. 3 or 4 a the pipe split severely as shown in Figure 21. Aluminum pipe alone was considered totally inadequate as the carrier.

In Test No. 6 a twelve inch length of five inch stainless steel tubing, approximately one-eighth inch wall thickness, was used as the carrier. A single 50 gram tetryl pellet was used and upon explosion the tubing bulged about the same as when 100 grams of tetryl was exploded in the mild steel

pipe (Test No. 4). The effect on the tubing is shown in Figure 22. The success of this test was considered borderline.

A combination of the stainless steel tubing inside the aluminum pipe is desirable for two reasons:

(a) the strength of the combination is greater than the pipe or tubing alone, and

(b) a sliding sleeve inside the pipe makes removal of the glass container easier.

The container supports are attached to a four inch length of the stainless steel tubing. Figure 10 illustrates the details explained below. The supports are two Plexiglas circles with holes in the center. The center holes are only large enough to allow the glass container to slip through. The Plexiglas supports are placed two inches apart in the sleeve to keep the glass container upright. Glass beads are attached to the container and these rest on the upper Plexiglas support. In this manner, the glass container is properly positioned with respect to the sleeve. The sleeve length chosen is four inches to reduce overall carrier weight without sacrifice of strength at the center where the carriers were bulging in the tests.

Once the carrier is passed through the outside steel wall in one of the areas, the sleeve is remotely raised with respect to the pipe. By raising the sleeve the glass container is exposed enough to be grasped with the manipulator

for further handling. The glass container inside the carrier during transport is illustrated in Figure 23A and Figure 23B shows the sleeve raised remotely and the glass container held with a manipulator for such an operation as pouring to another container.

The final two tests, No. 7 and 8, described previously, were identical and concluded the series. No further testing was necessary as the evolved carrier design met all requirements.